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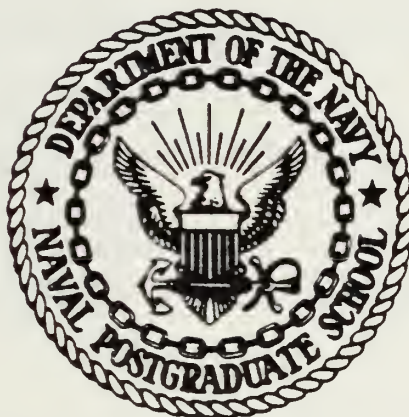
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# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



# THESIS

A Damage Assessment Model for Surface  
Engagement for Missile and Gunfire

by

Mario Ivan Carratu Molina

March 1982

Thesis Advisor: Wayne P. Hughes, Jr.

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A DAMAGE ASSESSMENT MODEL FOR SURFACE ENGAGEMENT FOR MISSILE  
AND GUNFIRE

BY

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COMMANDER, VENEZUELAN NAVY  
VENEZUELAN NAVAL ACADEMY, 1965

SUBMITTED IN PARTIAL FULFILLMENT OF THE  
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MASTER OF SCIENCE IN OPERATIONS RESEARCH

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1.



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## TABLE OF CONTENTS

	Page No.
I. INTRODUCTION -----	10
II. DAMAGE MODEL -----	13
A. GUNFIRE DAMAGE MODEL -----	13
1. Target Aspect Factor -----	14
2. Hit Probability as a Function of Range ---	18
3. Expected Damage Given a Hit -----	21
4. Sea State -----	21
5. Deceptive Jamming Factor -----	21
6. Rate of Fire -----	25
B. GUNFIRE DAMAGE CALCULATIONS -----	26
C. MISSILE DAMAGE MODEL -----	32
1. Expected Damage Given a Missile Hit ----- (range)	32
2. Missile Hit Probability as Function ----- of Range	32
3. Target Aspect Factor -----	35
4. Deceptive Jamming -----	35
5. Missile Impacts -----	35
6. Warhead Weight Factor -----	36
D. MISSILE DAMAGE CALCULATIONS -----	36
III. PROGRAM DESCRIPTION -----	38
A. INPUT -----	38





1. Datal -----	38
2. Data2 -----	39
B. PROGRAM RUN -----	40
C. PROGRAM OUTPUT -----	40
1. History1 File -----	40
2. History2 File -----	41
IV. RESULTS AND FUTURE IMPROVEMENTS -----	42
A. RESULTS -----	42
B. FUTURE IMPROVEMENTS -----	42
1. Validation -----	42
2. Tactical Improvements -----	43
APPENDIX A -----	44
LIST OF VARIABLES -----	44
COMPUTER PROGRAM LISTING -----	46
BIBLIOGRAPHY -----	56
INITIAL DISTRIBUTION LIST -----	57



## LIST OF TABLES

	Page No.
TABLE 1. Target Aspect Factors -----	17
TABLE 2. Beaufort Scale and Equivalent Sea State ----- Factor	24
TABLE 3. Target Elements Distribution -----	31



## LIST OF FIGURES

	Page No.
FIGURE 1. Projective Trajectory Showing Value of Incidence Angle ( $\Omega$ ) With Range -----	16
FIGURE 2. Graphical Representation of Hit Probabilities as a Function of Range for Gunfire (Blue) -----	19
FIGURE 3. Graphical Representation of Hit Probabilities as a Function of Range Gunfire (Red) -----	20
FIGURE 4. Expected Damage vs Range for Gunfire (Blue) -----	22
FIGURE 5. Expected Damage vs Range for Gunfire (Red) -----	23
FIGURE 6. Graphical Representation of Target Placement (A) and Covered Area (B) -----	29
FIGURE 7. Expected Damage vs Range for Missile Fire (Blue & Red) -----	33
FIGURE 8. Graphical Representation of Hit Probabilities as a Function of Range for VMissile Fire (Blue & Red) -----	34



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## I. INTRODUCTION

A war game is a dynamic presentation of military actions executed in such a way that one or more human participants can exercise control and take decisions against the activities of opposing forces in a real or hypothetical scenario. There are essential elements in war games which distinguish them from other simulations of military activities. They are:

- a. Force command and control (the combat decisions) for the opposing forces are made by human decision-makers.
- b. These decision-makers must react to the evolution of the combat and exercise their capabilities and experience in order to take decisions that later will reflect their accuracy or not in the outcome of the battle.

These characteristics make war games perhaps the only medium available, short of war, efficient enough for evaluating and examining command decisions at every level as well as constituting a tool to identify and isolate problems such as weapons limitations, forces weakness, logistic requirements, command and control, etc., as they arise during the execution and conduct of the operations; and in addition, the affect of the environment where forces are supposed to enact. More generally, a war game is a simulation, which is operated in accordance with predetermined rules, data, and procedures for selected aspects of a conflict situation.



Simulation also provides a means for gaining experience, and the development of analytical expertise and awareness of the systems available, without paying the penalties of a real world conflict.

In order to fulfill their objectives, war games must be realistic and reflect at every moment the sense of real conflict situations, where the players have the opportunity to exercise their skills in dealing with the variables in play. The author believes that one of the key points which contributes to the realism of the games is to have an accurate Damage Assessment procedure, from which people involved in the game could evaluate operational and tactical outcomes with respect to the decisions that they make.

In order to obtain this degree of realism, the people in charge of the damage assessment role must have valid and accurate information pertaining to vulnerability, reliability, accuracy and destructive power of weapons systems under consideration, as well as an unbiased appreciation of the power and weakness of the opposing forces. In addition, the players must be able to use the outcomes of the damage assessment process to develop capabilities and techniques to evaluate the performance effectiveness of the systems on hand and to take the optimal decision that the tactical situation and the ongoing operations require.

For the case of naval forces in a combat situation, it is necessary to have a means of assessing the damage to the



combatants as a function of their respective forces composition. The specification of such a damage function is not an easy task because of the varied roles that different force types play; and also because the interactions between force types can vary considerably with respect to the different characteristics which will add more complexity to the model.

This work presents a particular view of Surface Damage Assessment by considering Missile and Gunfire. The author uses a Monte Carlo technique in a stochastic process in which two opposing surface forces of one or more ships (Blue and Red) engage in a gun and missile battle.

The expected damage for each force is assessed by considering the following variables:

- A. Expected Damage Given One or More Hits.
- B. Target Aspect (angle).
- C. Rate of Weapons Fire.
- D. Jamming Factor.
- E. Weapon Hit Probability as a Function of Range.
- F. Sea State.

The simulation program combines a deterministic expected value model and chance elements by means of a routine written in Fortran IV using an IBM 3060 computer.

The Damage Assessment model will now be discussed in detail, followed by a description of how the variables were considered. A practical example of its implementation is then shown.



## II. DAMAGE MODEL

This chapter presents in detail the method followed in the development of the model. It also describes the factors taken into consideration in order to keep a sense of both realism and consistency.

The absence of a mathematical expression which permits the damage calculations and the variety of variables and parameters which has to be considered (e.g., platforms type, weapons, number of units) make the work difficult to accomplish, and it requires a great deal of research and real world experience to give the analyst the necessary background to cover all the areas of importance.

### A. GUNFIRE DAMAGE MODEL

The work was conducted using the bibliography available at the library of the Naval Postgraduate School. However, most of the material in this field is classified. Therefore it was necessary to create hypothetical, but reasonable, data in order to build the foundations to support the model. The damage calculations are realistic, but will not be necessarily accurate in detail until experimental data are obtained. The factors which were considered in the model are:

1. Target Aspect Factor (angle)
2. Hit Probability as a Function of Range





3. Expected Damage Given a Hit as a Function of Target Size
4. Sea State
5. Deceptive Jamming Factor
6. Weapons Rate of Fire

Each factor is presented in the following section with discussion as to how they were considered for model purposes.

1. Target Aspect Factor

For the purpose of the model, target aspect is the relative position of the target with respect to the opposing ship. It is defined as:

The smallest angle between the line of fire and the center line of the target ship.

The line of fire is the bearing of the point of aim from the center of the firing ship. If this line is within a given number of degrees, it will be an indication of the relative position of the target and the firing ship will have an angular value which reflects the characteristics of the ships considered.

In order to implement this factor into the model, a target size was chosen that was the average for the most common ships.

length      500 feet

width        55 feet

The next step was to combine target angle with the range in order to obtain a numerical value called Target Aspect



Factor which reflects how the relative angle and range of the target, with respect to the attacking ship, will affect the accuracy of the delivery of weapons.

The next step was to have a base range which was used as indication of position of the forces. It was necessary to split the range in three sections as follows:

Long Range =  $.9 \times$  Effective weapon range

Medium Range =  $.6 \times$  Effective weapon range

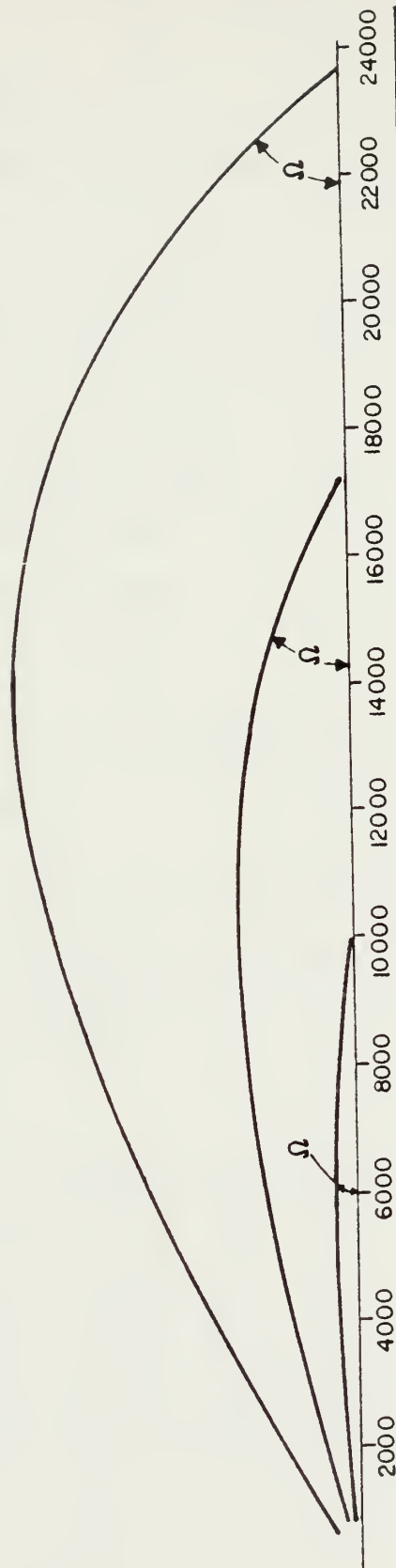
Short Range =  $.3 \times$  Effective weapon range

When the target range falls closest to the above values, then it is said that the target is at long, medium, or short range, respectively.

In order to combine Target Range and Target Angle, a mathematical relationship was developed by considering: Target Length, Target Width, and Target Angle, and the value of the angle formed by the projectile trajectory and target vertical plane. This angle will be called from now on the "Incidence Angle" ( $\Omega$ ). In order to determine the values for the incidence angle, it was found in the trajectory tables for 6 inch guns that this value changes with the range. The values were selected for long, medium, and short range; see Figure 1.

For long range, the  $\Omega$  value was 45 degrees. For medium range the  $\Omega$  value was 15 degrees. For short range the  $\Omega$  value was 3 degrees. The relationships expressed above are:





6 in. 53 cal. GUN
TRAJECTORIES
I.V. = 3000 F.S.
105 LB. M.C. PROJECTILE
NAVY DEPARTMENT
BUREAU OF ORDNANCE

FIGURE 1: PROJECTILE TRAJECTORY SHOWING  
VALUE OF INCIDENCE ANGLE ( $\Omega$ )  
WITH RANGE

RANGE	$\Omega$
SHORT	3°
MEDIUM	15°
LONG	45°



a. Short Range

$$\frac{1}{2} \sin (\text{Theta}) + w \cos (\text{Theta})$$

b. Medium Range

$$1 \sin (\text{Theta}) + \cos (\text{Theta}) [w = 1 \sin (\text{Omega})]$$

c. Long Range

$$1 \sin (\text{Theta}) + \cos (\text{Theta}) [w + 1 \sin (\text{Omega})]$$

Where:

Omega = Incidence Angle

Theta = Target Angle

1 = Target Length

w = Target Width

The values taken for Theta are 0, 15, 30, 45, 60, 75, 90 degrees.

Once the computations were completed and the values normalized, a matrix of target aspect factors was constructed as it is shown below in Table 1.

TABLE 1: Target Aspect Factors

	<u>0</u>	<u>15</u>	<u>30</u>	<u>45</u>	<u>60</u>	<u>75</u>	<u>90</u>
<u>Short</u>	<u>.22</u>	<u>.47</u>	<u>.69</u>	<u>.86</u>	<u>.90</u>	<u>1.02</u>	<u>1</u>
<u>Medium</u>	<u>.37</u>	<u>.61</u>	<u>.82</u>	<u>.96</u>	<u>1.05</u>	<u>1.06</u>	<u>1</u>
<u>Long</u>	<u>.80</u>	<u>1.04</u>	<u>1.20</u>	<u>1.28</u>	<u>1.27</u>	<u>1.17</u>	<u>1</u>





The above matrix shows the target factors values per range and per target angle. The reason for their behavior is because gunnery errors in range and deflection can usually be described by a normal distribution which is also represented by two parameters, Mean Error (ME) and Probably Error (PW). In the absence of bias, Mean Error is equal to Probable Error (ME=PE). In this case, then, the distribution of the errors is circular and the ME and PE are called Circular Error Probable (CEP). But in our case bias is present due to the delivery error of guns in the system and the distribution is Elliptical Normal with the deflection error smaller than range error. The result is that at long range when omega is greatest the target aspect factor is much less than at short range when the gunfire is nearly horizontal. That is the reason why the Target Aspect Factor decreases in relativity as the range increases.

## 2. Hit Probability as a Function of Range

Once again due to non-availability of real data, it was necessary to find a rational way to obtain numerical values which represent how accurate the weapons systems are and how they are affected by the range. Assuming that the probability of impact of the weapons decreases as the range increases, a graphical relationship was developed in order to have a source that would vary the values of hit probability with respect to range. For doing this two gun types were chosen (5 inch and 4.5 inch); see Figures 2 and 3.



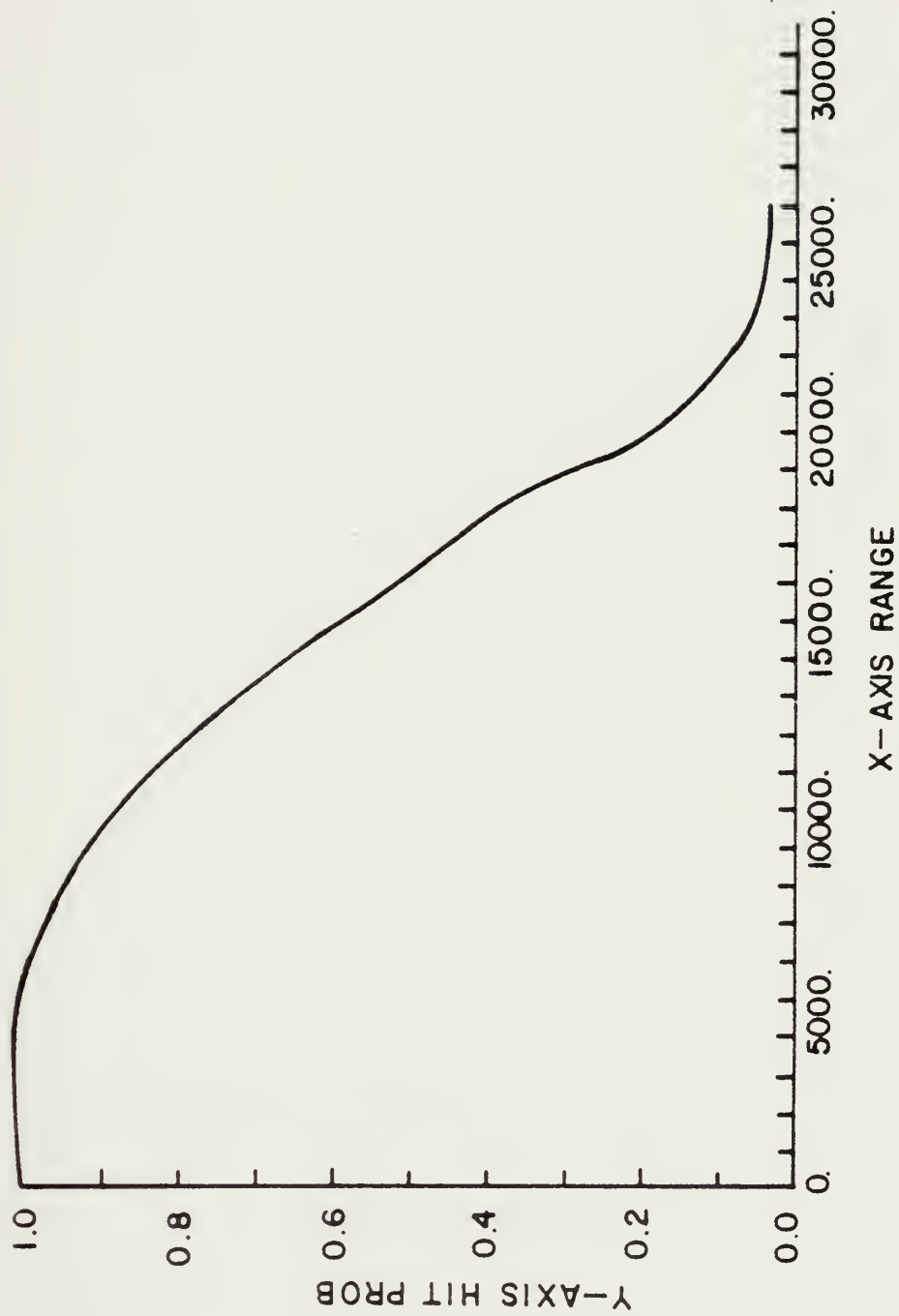


Figure 2. Graphical Representation of Hit Probabilities as a Function of Range for Gunfire (Blue)



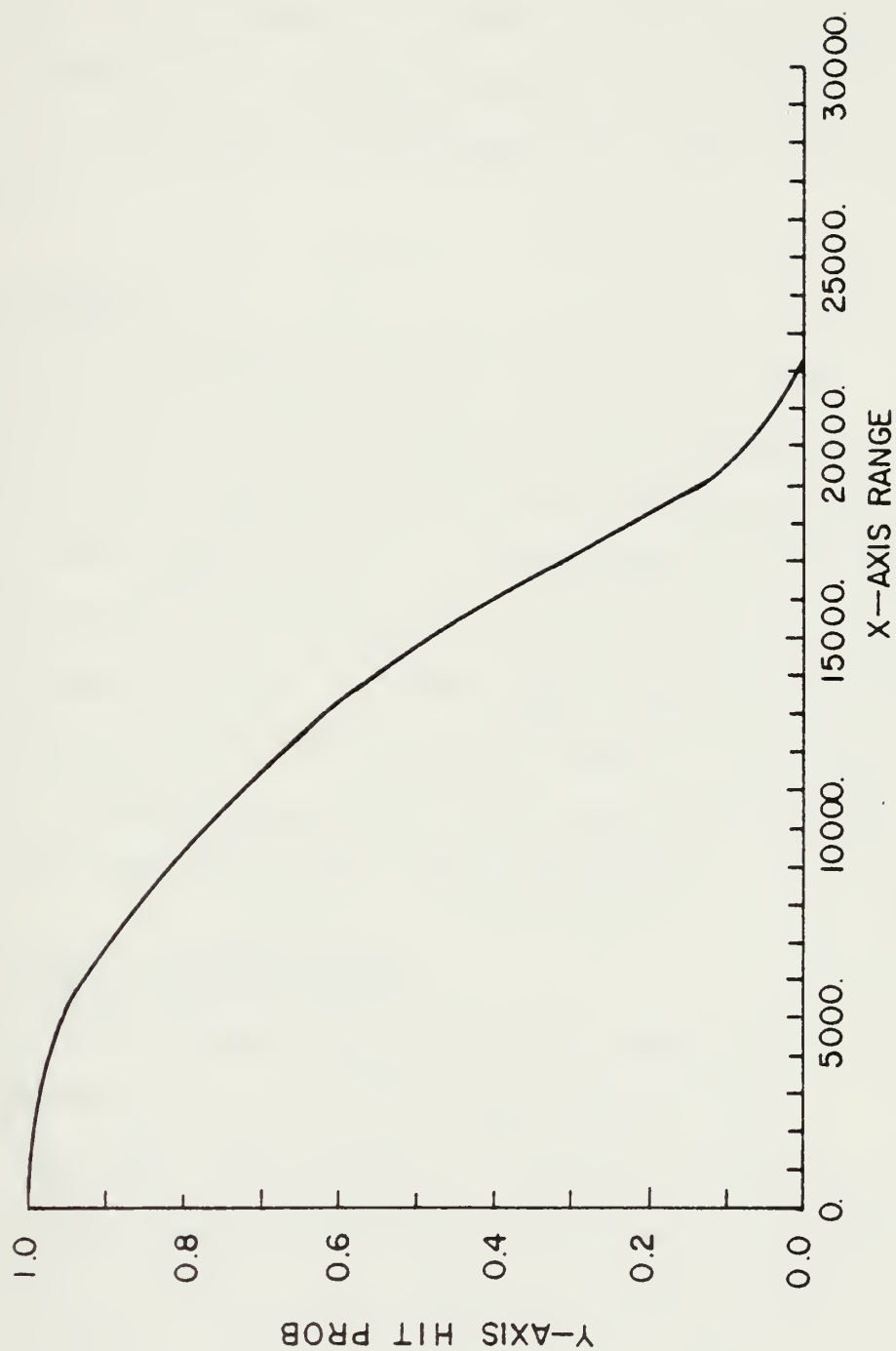


Figure 3. Graphical Representation of Hit Probabilities as a Function of Range for Gunfire (Red)



### 3. Expected Damage Given A Hit

For this a relationship was developed such that as the size of the target increases the expected damage due to critical hits will decrease. In other words, the degree of target vulnerability is inversely proportional to the target size. See Figure 4 and Figure 5 for Blue and Red, respectively.

### 4. Sea State

The sea condition is a well known factor which degrades the effectiveness and accuracy of the gunfire, where the personal capabilities and the stabilizations systems are down graded enough to considerably reduce the overall effectiveness of the system. The scale was used as a reference point to build a factor table which would have an equivalent factor for each Beaufort state. For values equivalent to Beaufort Scale 5 or above, the effectiveness of surface forces engagement are highly diminished. See Table 2.

### 5. Deceptive Jamming Factor

Deceptive jammers interfere with enemy gunfire control, the guidance of the missile weapons, and their acquisition systems. The effect of deceptive jammers is to increase the probable error and also to deflect the aimpoint back behind the center of the target with the results that the hit probability decreases. For the purpose of the model when deceptive jamming is being employed, a random





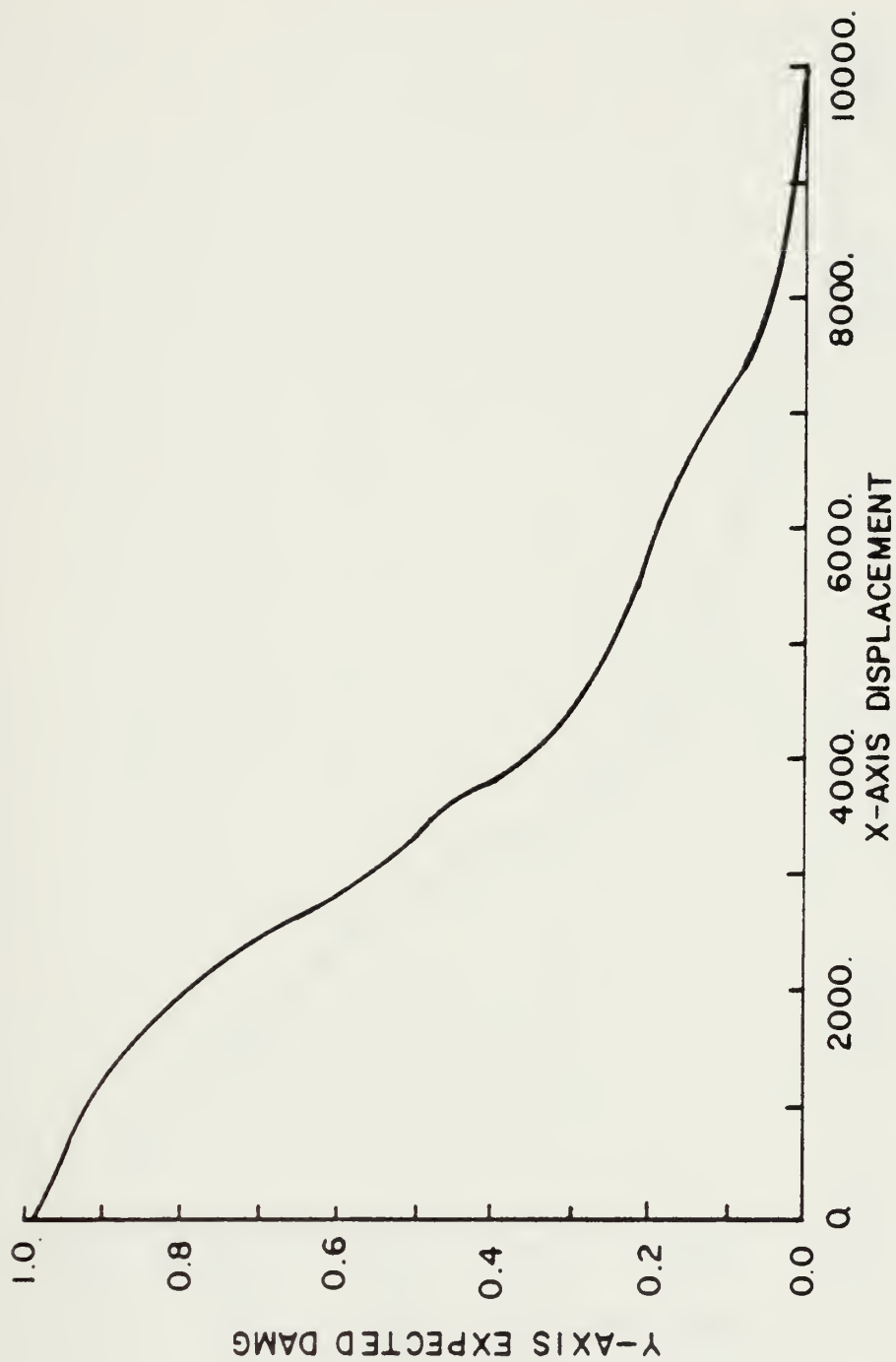


Figure 4. Expected Damage vs Range for Gunfire (Blue)



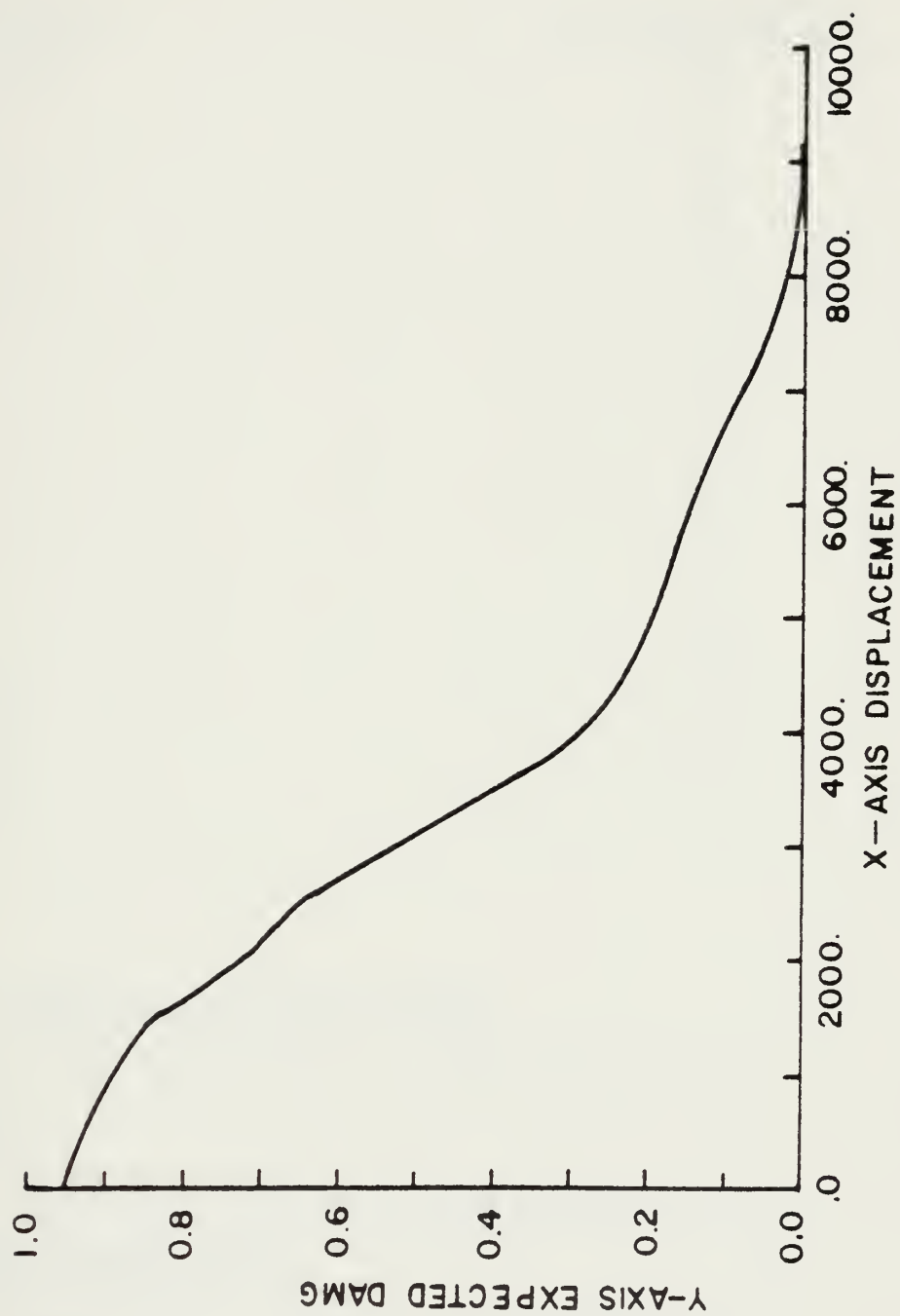


Figure 5. Expected Damage vs Range for Gunfire (Red)



TABLE 2. Beaufort Scale and Equivalent Sea State Factor

<u>Beaufort</u>	<u>Sea State Factor</u>
<u>0&amp;1</u>	<u>1.0</u>
<u>2</u>	<u>.8</u>
<u>3</u>	<u>.7</u>
<u>4</u>	<u>.7</u>
<u>5</u>	<u>.6</u>
<u>6</u>	<u>.5</u>
<u>7</u>	<u>.4</u>
<u>8</u>	<u>.4</u>
<u>9</u>	<u>.3</u>
<u>10</u>	<u>.3</u>
<u>11</u>	<u>.2</u>
<u>12</u>	<u>.1</u>

Aircraft Carriers and Battleships.

Total Life (slife) = Displacement/100

Carriers.

Total Life (slife) = Displacement/70

Destroyers and Frigates

Total Life (slife) = Displacement/30

Corvetes and below.



number is chosen between .5 and 1.0. This value represents in the model a reduction in the weapons effectiveness which goes from a maximum effect of .5 to a minimum effect of 0. There is no consideration of multiple deceptive jammers in the model.

## 6. Rate of Fire

One of the questions which varies with operational circumstances is, what rate of fire should be used? This factor depends upon the tactical situation, state of training, enemy characteristics, magazine capacity, etc.; but the rate of fire must be consistent with the individual ships' circumstances, and will often not be as much as the theoretical, or gunnery range maximum.

In war games it is common that the players expect unrealistically high rates of fire, since the more rounds that are fired accurately during the action, the higher the cumulative kill probability is. When different firing rates are considered, fewer rounds expended at a high rate of accuracy may be more effective than more rounds expended at a lower rate of accuracy.

For this model in particular, the rate of fire that will be allowed is an input which has to be decided by the umpire, depending upon the tactical situation, state of training, and weapons reliability.





## B. GUN FIRE DAMAGE CALCULATIONS

It was necessary to create a numerical value which represents the idea of life of the target. This value also represents in the model the target's capabilities to sustain damage; it will be reduced each time a hit occurs. For this purpose the displacement of the target in tons was considered to represent, in a way more or less tangible, the life of the ship along with a factor to use as a divisor in order to get what is believed to give a realistic relationship between hits and damage. This divisor changes for different targets or platforms. The total life value is derived in the following way:

$$\text{Total Life (slife)} = \text{Displacement}/20$$

The damage computations are conducted with the following steps:

1. For each interaction, a value of expected damage is obtained. It is called Expected Damage per Move. The value is computed by means of the following expression.

$$\text{EDMM} = [\text{Edam|Hit}] * \text{Ph} * \text{Rf} * \text{Seast} * \text{Xjamm} * \text{Tagta}$$

Where:

EDMM = Expected Damage per Move.

EDAM|hit = Expected Damage Given a Hit Occurs.

PH = Hit Probability of the Weapon

RT = Rate of Fire During the Engagement.

Seast = Sea State



Xjamm = Deceptive Jamming.

Tagta = Target Aspect Factor.

2. The residual target life is computed applying the following linear expression.

$$RLIFE = RLIFE \left( 1 - \sum_{L=1}^m EDMM \right)$$

3. The cumulative damage per move is simply the difference t life minus rlife.

$$CDPOINT = TLIFE - RLIFE$$

4. The percent floating capabilities is computed as follows.

$$FLOATC = (1 - CDPOINT/TLIFE) * 100$$

5. A coverage factor is required in order to establish how large the damage is to each ship's component along the target length.

$$SBAND = EDMM * TLENGTH$$

6. A location of where the target was hit was required and in order to do this the target length was considered as a base, ranging from zero (0) to five hundred (500), then a uniform random number was drawn. The number gives the physical location of the weapon hit on the target.



Once the hit place is determined, the next step is to find out which of the systems on board were knocked out or damaged. The hit place is considered the center. The upper bound of the hit will be the hit place plus half of the coverage factor, and the lower bound will be the hit place minus half of the coverage factor.

$$\text{DAMAGE AREA} = (\text{sband}/2 \leq \text{hplace} \leq \text{sband}/2)$$

An example of how hit placement, coverage factor, and target elements are determined is shown in Figure 6. Figure 6 is a sketch of a target type showing the target elements subject to suffering an amount of damage per move or during the engagement.

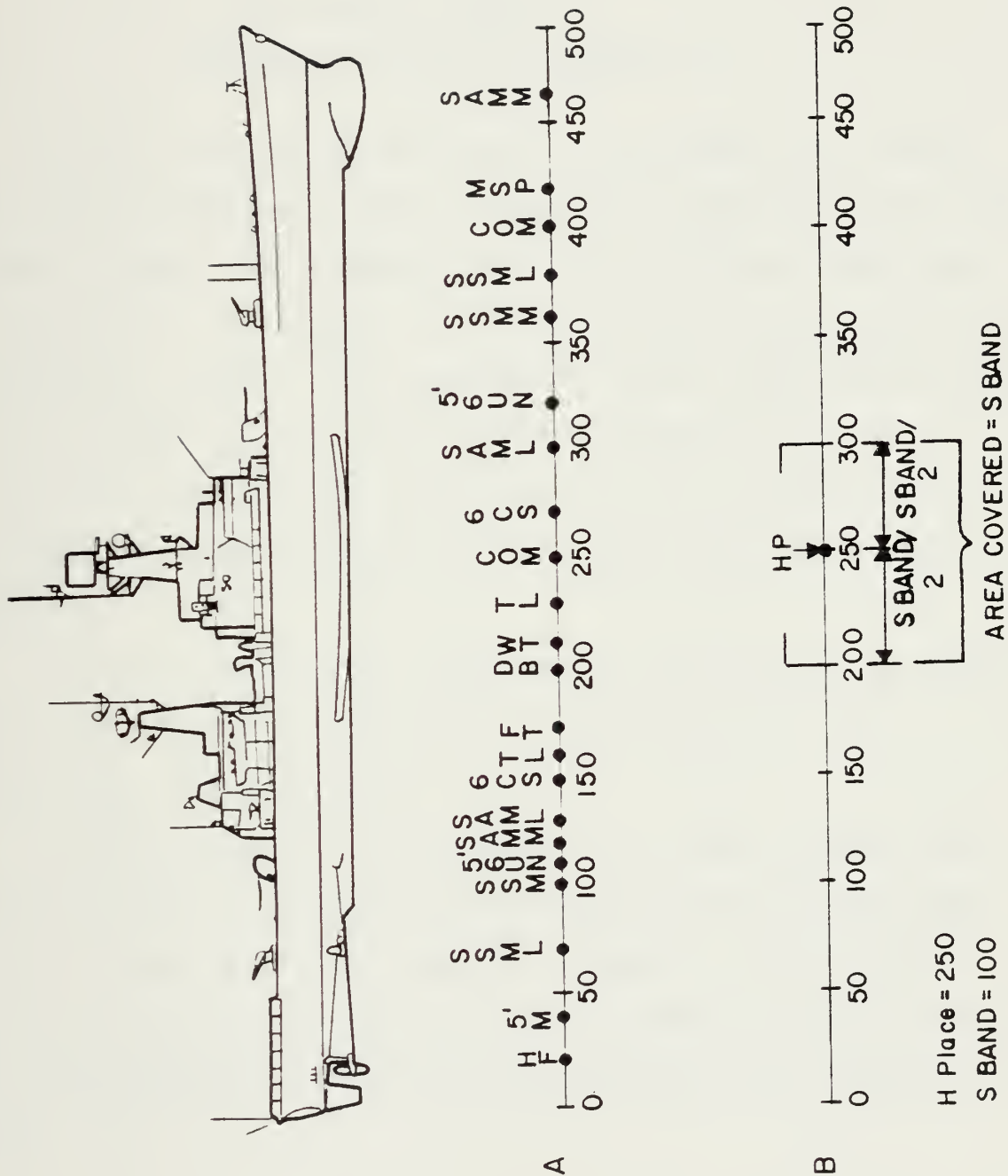
Line "A" shows where the target elements are placed along the target length from stern to bow.

Line "B" shows where the hit has occurred and how many target elements were subject to damage.

Let's suppose that the outcome of a uniform random number is 250. This number indicates that the place where the hit occurred was at 250' from stern to bow. The area of the ship suffering damage is given by the size of the Coverage Factor (SBAND) whose center is placed at hit place (HP). This physical dimension equals to  $\text{SBAND}/2$  ( $250 \pm 50$ ).

The actual target elements which suffer damage are those which are located within the area between 200' and 300'. For this particular example they are:









DAMAGE BRIGADE I  
WATER TANK  
TORPEDO LAUNCHER II  
COMMUNICATION SYSTEMS (UHF-HF)  
5" GUN CONTROL SYSTEM II  
SURFACE-AIR MISSILE LAUNCHER II

A first step before the start of the game is to locate the target elements as they are actually positioned along the target length. Each element is given an initial condition, a location on the target, an identification number, and, the degradation factor. The degradation factor indicates the percent of damage each target element suffers if it is hit; the amount of damage is cumulative per move. There are twenty-two target elements in the sample table shown below, Table 3.

Table 3 was used for a Red Target; one similar for Blue, but with different distribution elements and different factors was also designed.

After each move the players and the game director will have available a computer output showing the residual capability values of all the target's elements. These will be the input for the next move. Also a summary, called History, will be available with all the computations done during the game.



TABLE 3. Target Elements Distribution

<u>Target Element</u>	<u>Target Ident.</u>	<u>Target Place</u>	<u>Target Condition</u>	<u>Target Damage Factor</u>
HELO FUEL	1	10	28000 gals.	.25
5' MAGAZINE	2	40	100%	.50
SSML I	3	70	100%	.50
SSM MAGAZINE	4	100	4	.50
5' GUNd	5	110	100%	.50
SAM MAGAZINE	6	120	9	.50
SAML I	7	130	100%	.50
GUN C SYSTEM	8	150	100%	.50
TORPEDO L I	9	160	100%	.50
FUEL TANK	10	170	360 tons	.25
DAMGE BRIG. I	11	200	100%	.50
WATER TANK	12	210	20000 gals.	.25
TORPEDO L II	13	230	100%	.50
COM. HF UHF	14	250	100%	.50
GUN C SYSTEM II	15	270	100%	.50
SAML II	16	300	100%	.50
5' GUN	17	320	100%	.50
SSM MAGAZINE	18	360	4	.50
SSM L II	19	380	100%	.50
COM LF VHF	20	400	100%	.50
MAX SPEED	21	420	38K	.25
SAM MAGAZINE	22	460	9	.50

The damage to certain ship elements like Surface Radar, Electronic Countermeasures (passive and active), Air Radar, and the Helo, considered separately as a kill-no-kill calculation.



### C. MISSILE DAMAGE MODEL

The missile damage model basically follows the same structure as the gun fire model with slight differences in the factors under consideration. The factors considered are:

- a. Expected Damage per Missile Hit as a Function of Target Size.
- b. Missile Hit Probability as a Function of Range.
- c. Target Aspect.
- d. Sea State.
- e. Number of Missile Impacts.
- f. Warhead Factor.

These will be considered in more detail as follows.

#### 1. Expected Damage Given a Missile Hit (range)

As in the Gun Fire case, a set of values assuming a relationship between the range and the damage due to critical hits was developed from hypothetical data.

In Figure 7 this relationship is presented graphically showing how the damage due to critical hits decreases as the target size increases. One of these graphs was created for both Blue and Red forces.

#### 2. Missile Hit Probability as Function of Range

This is similar to the way it was treated for the Gun Fire case. It's graphical consideration is shown in Figure 8.



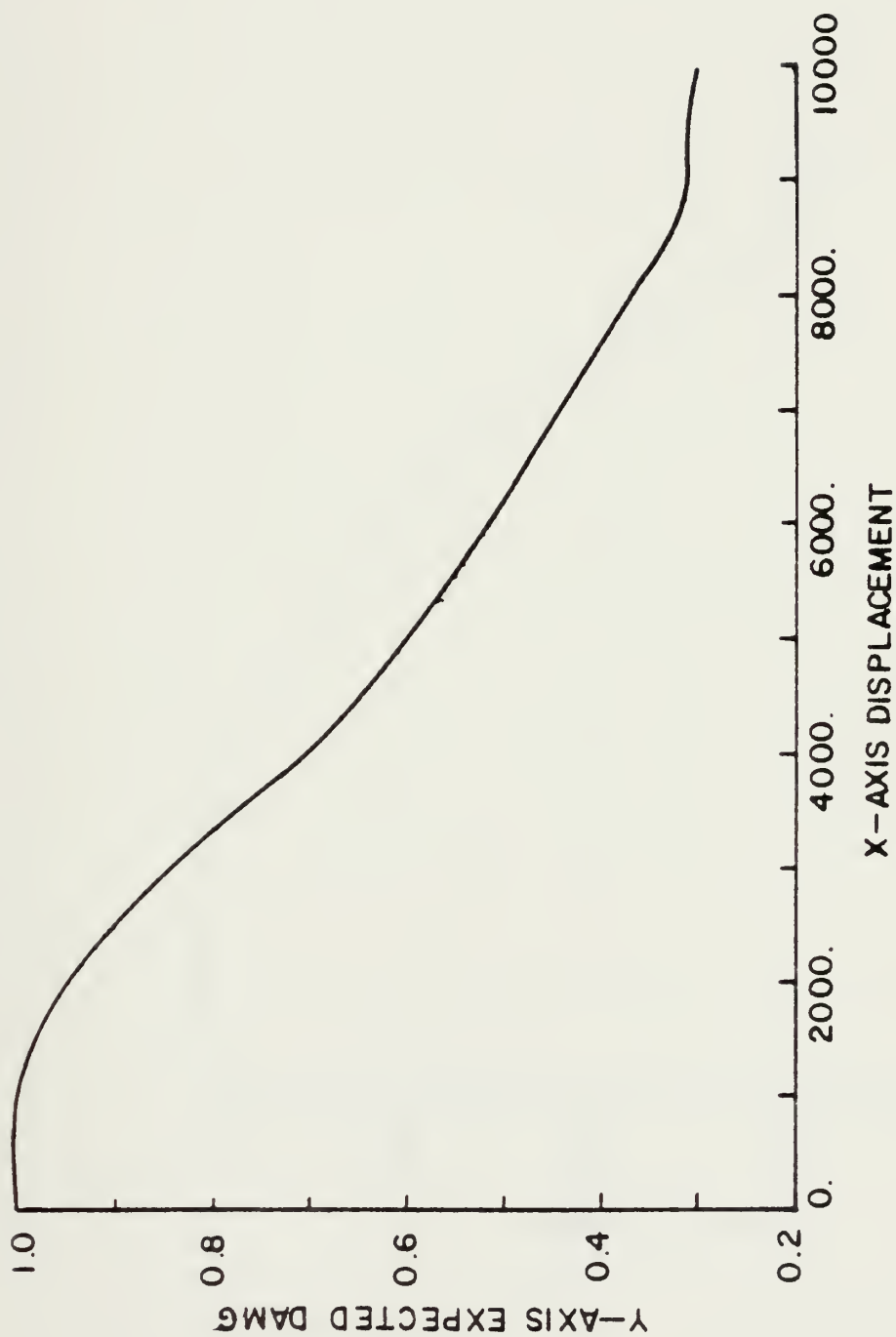


Figure 7. Expected Damage vs Range for Missile Fire (Blue & Red)





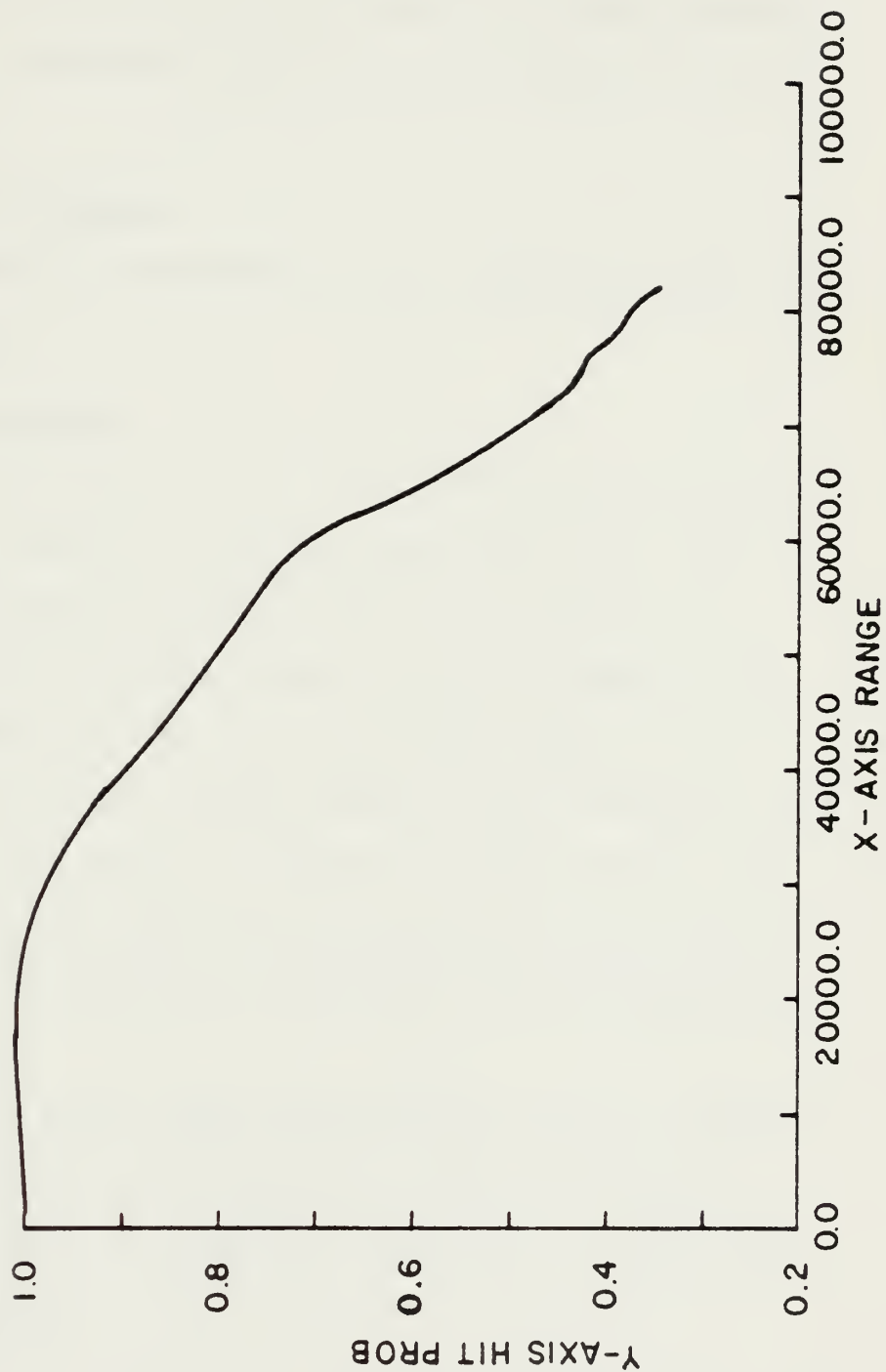


Figure 8. Graphical Representation of Hit Probabilities as a Function of Range for VMissile Fire (Blue & Red)



### 3. Target Aspect Factor

The missile model included the target aspect factor with a constant value equal to one (1). This is presented in this simple form because it will require further analysis which should be considered later as an improvement for the model.

### 4. Deceptive Jamming

This factor is considered in the same way it was for the Gun Fire case.

### 5. Missile Impacts

This factor was included as a multiplicative factor depending on the number of missiles remaining alive after considering the defense capabilities of the target ship. It was thought that a single target is able to shoot down the first incoming missile with probability equal to 0.7 and shoot down a second incoming missile with probability of 0.25. Using the technique of drawing a random number and comparing it with the above probabilities, we assess how many of the detected missiles constitute a surviving threat to the target ship.

Once we know the remaining missiles alive, we again pull a random number. By comparing it with the missile kill probability (0.7), we establish how many of them make impact on the target.



## 6. Warhead Weight Factor

Knowing that the destructive power of a missile mainly depends on the explosive charge it carries, the inclusion of this aspect was considered of great importance.

This factor was obtained as a ratio between the actual missile warhead weight and a warhead weight type. In this case, the weight of 250 pounds was taken as standard. This value is fed into the general expression to calculate the cumulative damage.

$$WHEAD = \text{MISSILE WARHEAD WEIGHT} / 250$$

Where:

$$WHEAD = \text{Warhead Factor}$$

### D. MISSILE DAMAGE CALCULATIONS

For missile damage calculations the following expression was used in order to compute the Expected Damage per Move:

$$EDMM = (EMHIT) * PHIT * IMPAT * XJAMM * WHEAD * SEAST * TAGTA$$

Where:

$$EDMM = \text{Expected Damage per Move}$$

$$EMHIT = \text{Expected Damage per Missile Hit}$$

$$PHIT = \text{Missile Hit Probability}$$

$$IMPAT = \text{Missile Impacts on Target}$$

$$XJAMM = \text{Deceptive Jamming Factor}$$

$$WHEAD = \text{Warhead Weight Factor}$$



TAGTA = Target Aspect Factor

SEAST = Sea State

After the expected damage per move has been computed, the rest of damage calculations are the same as in the gunfire model.





### III. PROGRAM DESCRIPTION

A computer program was written to support the model. The present chapter will explain in detail how it was used and how the data was handled. The listing of the computer program is presented in Appendix A.

The program is suitable to assess damage for any number of targets (in the example  $N = 4$ ), one at a time in two versions, Gun Fire and Missile Fire.

#### A. INPUT

Two sets of data were used for each force, independently, and were called Blue Datal, Blue Data2, Red Datal, and Red Data2. Those sets of data are shown in the appendix. They contain the following information in the order they appear.

##### 1. Datal

NAME OF THE SHIP	NS
TARGET RANGE	KRANGE
TARGET LENGTH	TARLE
TARGET WIDTH	TARWI
TARGET DISPLACEMENT	TONS
TARGET ANGLE	THETA
DEFENSE FACTOR	DIFAC
SEA STATE	SEAST
RATE OF FIRE	SRT



MISSILE HIT PROB.	ZPHIT
MISSILE WARHEAD WEIGHT	HWEIT
GUNFIRE RANGE	R1
MISSILE FIRE RANGE	R2
MAXIMUM GUN FIRE RANGE	MRANGE
DISPLACEMENT	DISP
EXPECTED DAMAGE/HIT	EDMH
TARGET RANGE	TAR
GUN HIT PROBS.	YHIT
SHORT RANGE TAGTA FACTOR	sFAC
MEDIUM RANGE TAGTA FACTOR	mFAC
LONG RANGE TAGTA FACTOR	ZFAC
TARGET ELEMENT IDENTIFICATION	IDENT
TARGET ELEMENT PLACE	TPLACE
TARGET ELEMENT DEGRATING FACTOR	TEFAC

## 2. Data2

TARGET ELEMENT CONDITION	TCOND
TOTAL LIFE	SLIFE
REMAINING LIFE	RLIFE
CCUMULATIVE DAMAGE	SUM
HIT PLACE	HPLACE
GAME TIME	GTIME
SEEDS	IX,IX1,IX2,IX3,IX4



## B. PROGRAM RUN

The program is fed with Data1 and Data2 per side each time we want to establish the amount of damage sustained for a target after a move has occurred. This procedure is to be done for each target separately. For the subsequent moves it is necessary to introduce the changes required by the new tactical conditions and with the prior damage results.

## C. PROGRAM OUTPUT

The outcome of each engagement will consist of two printed outputs which will be stored in files called History1 and History2 for each side, and will be a compilation of the moves. In order to identify to which side the file corresponds, a letter B (blue) or R (red) will be placed before the word history.

### 1. HISTORY1 File

This file will contain the following information:

Type of Engagement (Gun or Missile Fire)

Target Name

Number of Missiles Detected

Number of Missiles Shotdown

Number of Missiles Alive

Number of Missile Impacts on Target

Target Aspect Factor

Expected Damage per Move

Remaining Life

Cumulative Damage



Floating Capabilities

Total Life

Hit Probability (Gun or Missile) of Engagement

Hit Place

Deceptive Jamming Factor

Coverage Factor

Target Elements Hit in the Move

Residual Conditions of all Target Elements

## 2. HISTORY2 File

This file will contain the information concerned with the residual conditions of the targets considered in the game. This information will become the initial conditions for subsequent moves.





#### IV. RESULTS AND FUTURE IMPROVEMENTS

##### A. RESULTS

The objective of the model, namely to obtain more rapid, accurate and realistic results during the damage assessment process, has been achieved. By giving the results to the game director and to each player, more time will be gained for tactical decisions and play. As reliable, validated inputs are provided, the model will present realistic combat outcomes to assist in the development of improved tactical doctrine.

##### B. FUTURE IMPROVEMENTS

The present model was developed as a tool for war gaming damage assessment that provided accuracy, realism, and rapid computations during the conduct of the game.

Future improvements should include the following:

###### 1. Validation

The model was developed and tested to a great extent with hypothetical data due to the absence of real or experimental data. Such data should be acquired to confirm or improve the model's accuracy and reliability.



## 2. Tactical Improvements

- a. The model now only considers a surface naval engagement involving Gun and Missile fire. The expansion of the model to include other important aspects, such as the ASW Warfare, AAW Warfare, Torpedo Attack, and Mines will enhance the utility of the model.
- b. The expansion of the model by including the possibility of treating more than one platform at the same time will accelerate the Damage Assessment process.
- c. The consideration of the target aspect factor in a missile engagement is an important future refinement for accuracy, and in addition will show how this factor affects the outcome of the engagement.
- d. The inclusion of the effects of damage to the Command Control and Communications will introduce in the game a factor of vital importance which is often overlooked during the conduct of fleet exercises and war games.



## APPENDIX A

This appendix contains a list of variables in the order they appear in the program, a listing of the program, and inputs for force blue and red.

### LIST OF VARIABLES

SLIFE	TARGET TOTAL LIFE
TONS	TARGET DISPLACEMENT
XJAMM	DECEPTIVE JAMMING FACTOR
KRANGE	DETECTION RANGE
THETA	TARGET ASPECT ANGLE
MRANGE	MAXIMUM RANGE
TAGTA	TARGET ASPECT
SFAC	SHORT RANGE TARGET ASPECT FACTOR
TFAC	MEDIUM RANGE TARGET ASPECT FACTOR
ZFAC	LONG RANGE TARGET ASPECT FACTOR
DISPR	DISPLACEMENTS TYPE
FEDHR	EXPECTED DAMAGE AS FUNCTION OF TARGET SIZE (GUN)
JRGED	TARGET RANGE
SRF	RATE OF GUN FIRE
SEAST	SEA STATE
PHIT	GUN HIT PROBABILITY
NS	TARGET NAME
NM	NUMBER OF MISSILES DETECTED



PK1M	PROBABILITY OF KILL FIRST INCOMING MISSILE
PK2M	PROBABILITY OF KILL SECOND INCOMING MISSILE
DIFAC	TARGET ANTI-MISSILE DEFENSE FACTOR
SDC	TARGET ANTI-MISSILE DEFENSE CAPABILITY
MALIVE	NUMBER OF MISSILES ALIVE
IMPAT	NUMBER OF MISSILE IMPATS ON TARGET
WHEAD	MISSILE WARHEAD WEIGHT FACTOR
HWEIT	MISSILE WARHEAD WEIGHT
EMHIT	EXPECTED DAMAGE PER MISSILE HIT
SBAND	COVERED AREA
PHB	HIT PROBABILITY AS FUNCTION OF RANGE (GUN)
TARLE	TARGET LENGTH
CDMPO	CCUMULATIVE DAMAGE PER MOVE
RLIVE	TARGET REMAINING LIFE
FLCAP	TARGET FLOATING CAPABILITIES
HPLACE	HIT PLACE
HALF	HALF COVERED AREA
UHALF	UPPER BOUND COVERED AREA
THALF	LOWER BOUND COVERED AREA
HLPK	HELO DAMAGE PROBABILITY
PCPK	ECM DAMAGE PROBABILITY
SRPK	SURFACE RADAR DAMAGE PROBABILITY
ARPK	AIR RADAR DAMAGE PROBABILITY
ACPK	ECCM DAMAGE PROBABILITY









```

C      SLIFE= TONS/30
C      GENERATION OF UNIFORM RANDOM DEVIATES IN ORDER TO HAVE RANDOMIZE
C      JAMMING FACTOR. (UNIFORM FROM 0 TO 1.)
      CALL LRND(IX,Y,N,1,0)
      XJAMM=.5*Y+.5
      IF (KRNGE.LE. R1) GO TO 20
      GO TO 30
      20 WRITE(6,11)
      11 FORMAT(3X,11, GUNFIRE ENGAGEMENT')
      64 WRITE(6,64) NS
      64 FORMAT(3X,11, TARGET NAME= ',I4)
      K=6
      DO 1 I=1,K
      IF (THETA.GT.15(I-1)) GO TO 134
      GO TO 40
      1 CONTINUE
      40 CONTINUE
      SCALING MAXIMUM RANGE BY CONSIDERING 30,60,90 PERCENT OF MAX RANGE
      AS SHORT,MEDIUM AND LONG RANGE RESPECTIVELY.
      SHORT=MRNGE*.3
      MDIUM=MRNGE*.6
      LONG= MRNGE*.9
      SELECTION OF TARGET ASPECT FACTOR (ANGLE) AS AFUCTION OF RANGE
      IF (KRNGE .LE. SHORT) GO TO 42
      IF (KRNGE .LE. MDIUM .AND. KRNGE.GT. SHORT) GO TO 50
      IF (KRNGE .LE. MRNGE .AND. KRNGE.GT. MDIUM) GO TO 60
      GO TO 80
      42 TAGTA=SFAC(I)
      GO TO 70
      50 TAGTA=TFAC(I)
      GO TO 70
      60 TAGTA=ZFAC(I)
      GO TO 70
      70 WRITE(6,12) TAGTA
      COMPUTATION OF EXPECTED DAMAGE GIVEN A HIT PER WEAPON
C      C      C

```

FAK000480  
 FAK000490  
 FAK000500  
 FAK000510  
 FAK000520  
 FAK000530  
 FAK000540  
 FAK000550  
 FAK000560  
 FAK000570  
 FAK000580  
 FAK000590  
 FAK000600  
 FAK000610  
 FAK000620  
 F

FAK000640  
 FAK000650  
 FAK000660  
 FAK000670  
 FAK000680  
 FAK000690  
 FAK000700  
 FAK000710  
 FAK000720  
 FAK000730  
 FAK000740  
 FAK000750  
 FAK000760  
 FAK000770  
 FAK000780  
 FAK000790  
 FAK000800  
 FAK000810  
 FAK000820  
 FAK000830  
 FAK000840  
 FAK000850  
 FAK000860  
 FAK000870  
 FAK000880  
 FAK000890  
 FAK000900  
 FAK000910  
 FAK000920  
 FAK000930  
 FAK000940









FAK01430  
FAK01440  
FAK01450  
FAK01460  
FAK01470  
FAK01480  
FAK01490  
FAK01500  
FAK01510  
FAK01520  
FAK01530  
FAK01540  
FAK01550  
FAK01560  
FAK01570  
FAK01580  
FAK01590  
FAK01600  
FAK01610  
FAK01620  
FAK01630  
FAK01640  
FAK01650  
FAK01660  
FAK01670  
FAK01680  
FAK01690  
FAK01700  
FAK01710  
FAK01720  
FAK01730  
FAK01740  
FAK01750  
FAK01760  
FAK01770  
FAK01780  
FAK01790  
FAK01800  
FAK01810  
FAK01820  
FAK01830  
FAK01840  
FAK01850  
FAK01860  
FAK01870  
FAK01880  
FAK01890  
FAK01900

```

K=0
WRITE(6,15) NM
15 FORMAT(3X, NUMBER OF INCOMING MISSILES DETECTED=',I4)
PK1M=.25
PK2M=.25
CALL SRND(IX1,ZZ,N,1,0)
RT1(I)=ZZ
SDC(I)=DIFAC*RT1(I)
IF(SDC(I).LE.PK1M).AND.(SDC(I).GT.PK2M) GO TO 110
IF(SDC(I).LE.PK2M) GO TO 120
110 K=K+1
WRITE(6,16) K
16 FORMAT(3X, INCOMING MISSILE SHUTDOWN=',I4)
120 K=K+1
WRITE(6,17) K
17 FORMAT(3X, INCOMING MISSILE SHUTDOWN=',I4)
IF(NM.LE.6) GO TO 1000
GO TO 130
130 MALIVE=NM-K
WRITE(6,18) MALIVE
18 FORMAT(3X, NUMBER OF MISSILES ALIVE=',I4)
IF(MALIVE.GT.0) GO TO 140
GO TO 1000
140 IMPAT=0
DO 5 I=1, MALIVE
CALL SRND(IX2,YZ,N,1,0)
RT2(I)=YZ
IF(RT2(I).GT.ZPHIT) GO TO 5
IMPAT=IMPAT+1
5 CONTINUE
IF(IMPAT.GT.0) GO TO 150
IMPAT=0
150 WRITE(6,19) IMPAT
19 FORMAT(3X, NUMBER OF IMPACTS ON TARGET=',I4)

COMPUTATION OF EXPECTED DAMAGE AS FUNCTION OF TARGET SIZE

DO 6 I=1,21
IF(TONS.LE.DISP(I)) GO TO 160
CONTINUE
6 T=TONS-DISP(I-1)
160 Q=DISP(I)-DISP(I-1)
P=T/Q
T=EDMH(I)-EDMH(I-1)
Q=P*T
EXPM=EDMH(I-1)+Q

```

CCCCC





```

PHIT=EXPM
COMPUTATION OF KILL PROBABILITIES AS A FUNCTION OF RANGE
DO 7 I=1,21
IF (KRNGE.LE. TAR(I)) GO TO 170
CONTINUE
7 TT=KRNGE- TAR(I-1)
170 QQ=TAR(I)-TAR(I-1)
PP=TT/QQ
TT=YHIT(I)-YHIT(I-1)
QQ=PP*TT
EMHIT=YHIT(I-1)+QQ
PEDHR=EMHIT

COMPUTATION OF DAMAGE PER MOVE AS A FCN OF EXPECTED DAMAGE PER
NUMBER OF MISSILE IMPACTS, WARHEAD JAMMING FACTOR,KILL PROBABILITY
WHEAD=HWEIT/250
TAGTA=1.
EDMM=EMHIT*PHIT*IMPAT*XXJAMM*WHEAD*TAGTA*SEAST
PEDHR=EMHIT

COMPUTATION OF WEAPONS COVERAGE AREA ON THE TARGET
500 SBAND=EDMM*TARLE

COMPUTATION OF REMAINING TARGET LIFE AFTER EACH MOVE
SUM=EDMM+SUM
RLIFE=SLIFE(1-(SUM))

COMPUTATION OF CUMMULATIVE DAMAGE
CDMPO=SLIFE-RLIFE

TARGET FLOATING CAPABILITIES AFTER EACH MOVE
FLCAP=(1-(CDMPO/SLIFE))1.00
IF (FLCAP.GT. 0.) GO TO 190
GO TO 999

GENERATION OF UNIFORM RANDOM DEVIATES IN ORDER TO ASSET LOCATION OF
WEAPON IMPACT UPON THE TARGET.
190 CALL LRND (IX3,YY,N,1,0)

```

FAK01910  
 FAK01920  
 FAK01930  
 FAK01940  
 FAK01950  
 FAK01960  
 FAK01970  
 FAK01980  
 FAK01990  
 FAK02000  
 FAK02010  
 FAK02020  
 FAK02030  
 FAK02040  
 FAK02050  
 FAK02060  
 FAK02070  
 FAK02080  
 FAK02090  
 FAK02100  
 FAK02110  
 FAK02120  
 FAK02130  
 FAK02140  
 FAK02150  
 FAK02160  
 FAK02170  
 FAK02180  
 FAK02190  
 FAK02200  
 FAK02210  
 FAK02220  
 FAK02230  
 FAK02240  
 FAK02250  
 FAK02260  
 FAK02270  
 FAK02280  
 FAK02290  
 FAK02300  
 FAK02320  
 FAK02330  
 FAK02340  
 FAK02350  
 FAK02360  
 FAK02370  
 FAK02380



```

HPLACE=500*YY
DETERMINATION OF THE TARGET ELEMENTS WHICH WERE HIT OR ARE LOCATED
WHITIN IMPACT AREA.
C C C C C
HALF=SBAND/2
UHALF=HPLACE+HALF
THALF=HPLACE-HALF
C C C C C
CALCULATIONS OF SENSORS KILL- NOT- KILL DAMAGE FOR AIR RADAR
SURFACE RADAR, ECM, ECCM, AND DAMAGE FOR HELO ON BOARD.
HLPK=.8
PCPK=.7
SRPK=.5
ARPK=.4
ACPK=.2
CALL LRND (IX4,X,N,1,0)
SES=YYY
IF (SES .GT. .AND.SES .LE. ACPK) GO TO 51
IF (SES .GT. ACPK .AND. SES .LE. ARPK) GO TO 61
IF (SES .GT. ARPK .AND. SES .LE. SRPK) GO TO 71
IF (SES .GT. SRPK .AND. SES .LE. PCPK) GO TO 81
IF (SES .GT. PCPK .AND. SES .LE. HLPK) GO TO 91
IF (SES .GT. HLPK) GO TO 999
51 WRITE(6,31)
GO TO 999
61 WRITE(6,32)
GO TO 999
71 WRITE(6,33)
GO TO 999
81 WRITE(6,34)
GO TO 999
91 WRITE(6,35)
999 J=22
DETERMINATION OF DAMAGE DEGRADATION OF TARGET ELEMENTS BY TAKING
IN CONSIDERATION THEIR INDIVIDUALS DAMAGE FACTORS.
C C C C C
WRITE(6,22)
22 FORMAT(3X,1)
WRITE(6,23) DAMAGE RESUMEN '
SBAND
WRITE(6,24)

```

FAK02390  
 FAK02400  
 FAK02410  
 FAK02420  
 FAK02430  
 FAK02440  
 FAK02450  
 FAK02460  
 FAK02470  
 FAK02480  
 FAK02490  
 FAK02500  
 FAK02510  
 FAK02520  
 FAK02530  
 FAK02540  
 FAK02550  
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 FAK02790  
 FAK02800  
 FAK02810  
 FAK02820  
 FAK02830  
 FAK02840  
 FAK02850  
 FAK02860



```

24 FORMAT(//,5X,' TARGET ELEMENTS WHICH WERE DAMAGE DURING THE MOVE
      ,//)
25 FORMAT(5X, TARIDENT',5X 'TARPLACE',5X,' TARCOND',)
      FAK02870
      FAK02880
      FAK02890
      FAK02900
      FAK02910
      FAK02920
      FAK02930
      FAK02940
      FAK02950
      FAK02960
      FAK02970
      FAK02980
      FAK02990
      FAK03000
      FAK03010
      FAK03020
      FAK03030
      FAK03040
      FAK03050
      FAK03060
      FAK03070
      FAK03080
      FAK03090
      FAK03100
      FAK03110
      FAK03120
      FAK03130
      FAK03140
      FAK03150
      FAK03160
      FAK03170
      FAK03180
      FAK03190
      FAK03200
      FAK03210
      FAK03220
      FAK03230
      FAK0324
      FAK033a

      DO 10 I=1,J
      IF (TPLACE(NS,I) .LT. THALF .OR. TPLACE(NS,I) .GT. UHALF) GO TO 10
      GO TO 210
      TCOND(NS,I)=TCOND(NS,I) - TEFAC(NS,I)*TCOND(NS,I)
      IF (TCOND(NS,I) .LT. 0.) TCOND(NS,I)=0.
      WRITE(6,26) IDENT(NS,I), TPLACE(NS,I), TCOND(NS,I)
10 CONTINUE
      WRITE(6,27)
      WRITE(6,28)
27 FORMAT(//,5X,' SURVIVAL CONDITION OF ALL TARGET ELEMENTS AFTER MOVE
      ,//)
28 FORMAT(5X, TARIDENT',5X 'TARCONDE',5X 'TARFACTOR',5X 'TARPLACE',
      WRITE(6,29) (IDENT(NS,I), TCOND(NS,I), TEFAC(NS,I), TPLACE(NS,I), I=1
      ,J)
25 FORMAT(3X, ' RANGE BIGGER THAN DETECTION RANGE')
12 FORMAT(3X, ' TARGET ASPECT=',F8.3)
29 FORMAT(//,6X,I4,9X,F8.1,4X,F8.3,4X,F8.1,/)
26 FORMAT(//,6X,I4,9X,F8.1,7X,F8.2,/)
23 FORMAT(3X, ' EXPECTED DAMAGE HIT=',F8.3,/,4X 'EXPECTED DMAGE PER
      MOVE=',F8.3,/,4X 'RMANNING LIFE=',F8.3,/,4X 'CUMM DAME=',F8.3,/,
      4X 'FLOATING CAP=',F8.3,/,3X 'TAL LIFE=',F8.3,/,3X 'HIT PROBAB
      ILY=',F8.3,/,3X 'HIT PLACE=',F8.3,/,3X 'JAMMING FACTOR=',F8.3
      ,/)
31 FORMAT(3X, ' COVERAGE FACTOR=',F8.3,/)
32 FORMAT(3X, ' ACTIVE COUNTERMEASURES CAPABILITIES LOST' )
33 FORMAT(3X, ' AIR DETECTION CAPABILITIES LOST')
34 FORMAT(3X, ' SURFACE DETECTION CAPABILITIES LOST')
35 FORMAT(3X, ' PASSIVE COUNTERMEASURES CAPABILITIES LOST')
      GTIME=GTIME+3
C1000 WRITE(6,206)
C 206 FORMAT(3X, ' NO AIRBORNE MISSILE AT THE MOMENT')
1000 WRITE(4,DATA2)
      STOP
      END
C C BLUE DATA ONE
C C
C DATA 1
NS=4
KRNGE=39678,
TARLE=500.,
TARWI=55.,
TONS=5643.,

```



















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Thesis

C27174 Carratu Molina

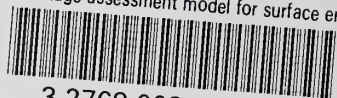
c.1

A damage assessment  
model for surface en-  
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